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APPENDIX A

CONVERSION UNITS

Key Property	SI Units	Multiply By:	To Convert to English Units
Viscosity	mPa-s	1.0	centipoise, cPs
Tensile strength	MPa	145	psi
Modulus of Elasticity	GPa	145×10^3	psi
Impact strength	J/m	1.88×10^{-2}	ft-lb/in

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APPENDIX B

Composition (%)	Mechanical Properties				
	Tensile Strength (MPa)	Tensile modulus (MPa)	Flexural strength(MPa)	Flexural modulus (MPa)	Impact strength(J/m)
* R40, F0	133.4 ± 8.2	10,525 ± 495	240.2 ± 7.7	11,584 ± 374	477 ± 19
R30, F0	97.3 ± 8.4	8,916 ± 58	185.1 ± 9.4	9,765 ± 266	364 ± 11
R25, F0	82.9 ± 6.3	8,010 ± 151	159.3 ± 5.6	8,491 ± 401	304 ± 13
R20, F0	63.3 ± 7.6	7,247 ± 265	130.1 ± 12.5	7,273 ± 315	250 ± 8
R40, F20	143.2 ± 7.3	12,084 ± 338	256.7 ± 8.5	12,832 ± 511	517 ± 14
R30, F20	106.2 ± 10.1	10,353 ± 470	200.3 ± 13.4	10,353 ± 409	395 ± 17
R25, F20	88.1 ± 5.0	9,457 ± 381	175.2 ± 9.1	9,457 ± 463	336 ± 12
R20, F20	70.4 ± 6.7	8,608 ± 357	142.3 ± 8.2	8,656 ± 381	273 ± 16

(over)

continued

Composition (%)	Mechanical Properties				
	Tensile Strength (MPa)	Tensile modulus (MPa)	Flexural strength(MPa)	Flexural modulus (MPa)	Impact strength(J/m)
R40, F40	155.1 ± 9.4	13,354 ± 550	279.0 ± 9.7	13,949 ± 289	563 ± 17
R30, F40	113.2 ± 8.2	11,611 ± 358	214.2 ± 11.3	11,970 ± 324	428 ± 20
R25, F40	91.2 ± 7.7	10,938 ± 510	182.5 ± 12.6	10,855 ± 356	360 ± 9
R20, F40	74.2 ± 9.0	10,108 ± 289	150.1 ± 10.1	10,033 ± 435	293 ± 13
R40, F60	165.7 ± 11.2	14,665 ± 315	298.5 ± 13.8	15,611 ± 708	608 ± 22
R30, F60	120.9 ± 10.5	13,453 ± 188	227.0 ± 7.1	13,260 ± 596	461 ± 18
R25, F60	99.4 ± 6.0	12,597 ± 530	192.0 ± 10.2	11,674 ± 514	387 ± 20
R20, F60	77.0 ± 7.4	11,368 ± 462	157.0 ± 8.8	10,964 ± 428	314 ± 15

(over)

continued

Composition (%)	Mechanical Properties				
	Tensile Strength (MPa)	Tensile modulus (MPa)	Flexural strength(MPa)	Flexural modulus (MPa)	Impact strength(J/m)
R40, F80	182.4 ± 6.5	15,328 ± 360	309.6 ± 17.9	17,077 ± 533	655 ± 36
R30, F80	137.0 ± 8.3	14,295 ± 294	238.5 ± 11.7	14,403 ± 371	501 ± 24
R25, F80	107.1 ± 10.1	13,387 ± 255	203.0 ± 8.3	13,342 ± 420	418 ± 17
R20, F80	82.3 ± 7.6	12,186 ± 304	168.7 ± 9.4	11,728 ± 157	335 ± 21

* R40,F0 : 40% by weight of glass fiber in the resin mix, 0% by weight of CaCO₃ in the resin.

APPENDIX C

Mechanical Tests for SMC Composites

1. Tensile Test (ASTM D638M-86)

Tensile strength is a measure of the resistance of a material to stress pulling in opposite direction. A taut guitar string is an example of tensile stress. When tensile specimens are tested they are said to be pulled in tension.

SMC specimens are machined to the shape of a dumbbell, as noted in Figure 1. They are cut to the dumbbell shape on a tensile contour cutter.

$$\text{Tensile strength (kg/mm}^2\text{)} = \frac{\text{load (kg)}}{\text{cross-sectional area (mm}^2\text{)}}$$

Load is the ultimate load to cause failure of the specimen. Cross-sectional area is the width x the thickness of the neck area. If there is a variation in dimensions, measurement is taken at the smallest area. Performing the tensile test is shown in figure 2.

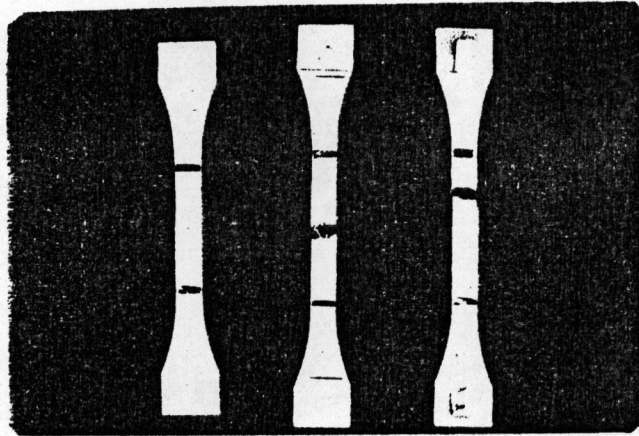


Figure 1 Tensile specimen as a dumbbell shape

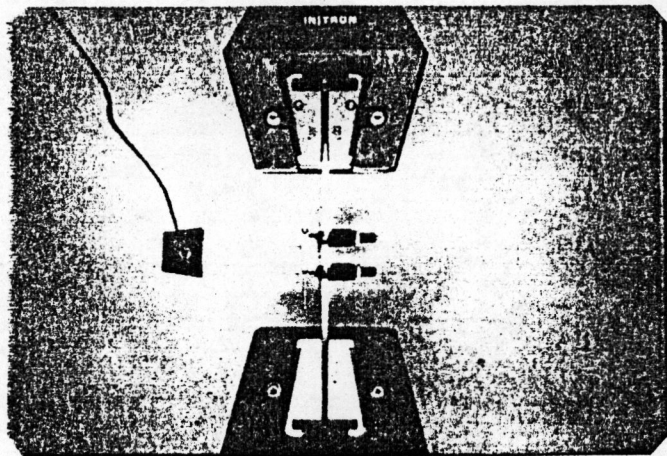


Figure 2 Performing the tensile test

2. Modulus of Elasticity (ASTM D638M-86)

This is the measurement of the stiffness of a rigid material when it is subjected to tensile or flexural forces. When a specimen is pulled in tension (tensile), it gets longer and narrower. If the load is removed, it will recover its original dimensions, providing it has not been stressed beyond its elastic limit, the load beyond which the specimen starts to undergo permanent distortion. Permanent distortion is known as permanent set, or permanent deformation. Figure 3 shows a typical stress-strain curve plotted during the testing of a specimen. The straight-line portion represents all loads within the elastic limit. Modulus can be computed anywhere along this line. All loads on the curved portion beyond the yield load will cause permanent deformation. Hooke's Law states that when a load is applied to a material, the stress is directly proportional to the strain-within the elastic limit.

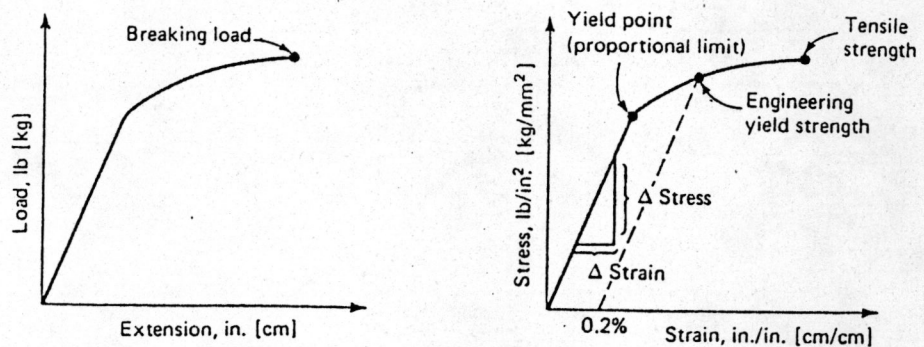


Figure 3 A typical stress-strain curve plotted during the testing of a specimen.

$$\text{Modulus (kg/mm}^2\text{)} = \frac{\text{stress kg/mm}^2}{\text{strain (mm/mm)}}$$

$$\text{Stress (kg/mm}^2\text{)} = \frac{\text{load (kg)}}{\text{cross-sectional area (mm}^2\text{)}}$$

3. Elongation (ASTM D638M-86)

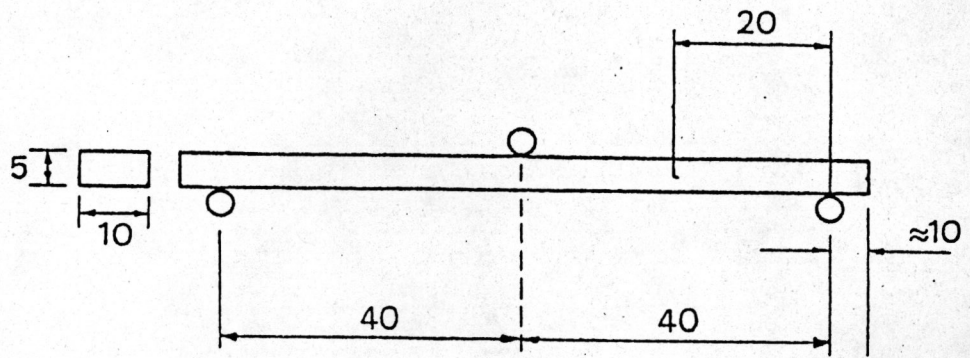
Elongation is the distance that a specimen stretches when pulled in tension. For SMC is rigid material, the stretch is short. In experimental testing it can be directly computed from electronic extensometer measurement.

$$\text{Total elongation (\%)} = \frac{(\text{ultimate length} - \text{original length}) \times 100}{\text{original length}}$$

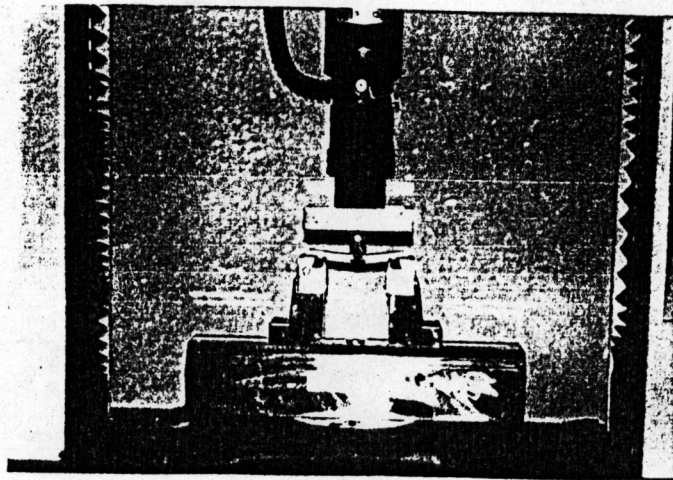
4. Flexural Strength (ASTM D790M - 86)

Flexural stress is a combination of tensile and compressive forces. Specimen was cut in a size of 100 x 10 x 5 mm (5 mm is a thickness of specimen). The span and width depend upon thickness, in this case the span is 80 mm.

A tested specimen is placed on a fixture having a supporting upright near each end as demonstrated in Figure 4.



(a)



(b)

Figure 4 Load and 3-supportings for flexural test:

(a) specimen geometry and loading, all dimensions are in mm

(b) flexural test setup

$$\text{Ultimate flexural strength (kg/mm}^2\text{)} = \frac{3PL}{2bd^2}$$

where :

P = load to cause failure (kg)

L = support span (mm)

b = width of specimen beam (mm)

d = thickness or depth of specimen beam (mm)

5. Flexural modulus (ASTM D790M-86)

It is the ratio within the elastic limit of stress to corresponding strain and shall be expressed in kg/mm² or megapascal. It is calculated by drawing a tangent to the steepest initial straight-line portion of the load-deflection curve and using following equation.

$$\text{Flexural Modulus, } E_B \text{ (kg/mm}^2\text{)} = \frac{L^3 m}{4bd^3}$$

where : E_B = Flexural Modulus (kg/mm²) or MPa

L = support span (mm)

b = width of specimen beam (mm)

d = thickness or depth of specimen beam (mm)

m = slope of the tangent to the initial straight line portion of the load-deflection curve (kg/mm²) of deflection.

6. Izod Impact Strength (ASTM D256M-86)

Izod impact strength indicates the energy required to break notched specimens under standard conditions. It is used to measure a material's ability to withstand shock loading. The classical definition of impact strength is the energy required to fracture a given volume of material. The units of this property as reported in the literature as Joules (J) or Joules/m in the SI-unit system.

The specimen is clamped at the base of the machine with the notch facing the direction of impact. The pendulum is released, and the reading is indicated by a pointer that is pushed along by the pendulum in its follow-through. The force consumed in breaking the sample is calculated from the height that the pendulum reaches on the follow-through. Figure 5 shows the Impact testing machine for Izod test and the position of sample on the machine.

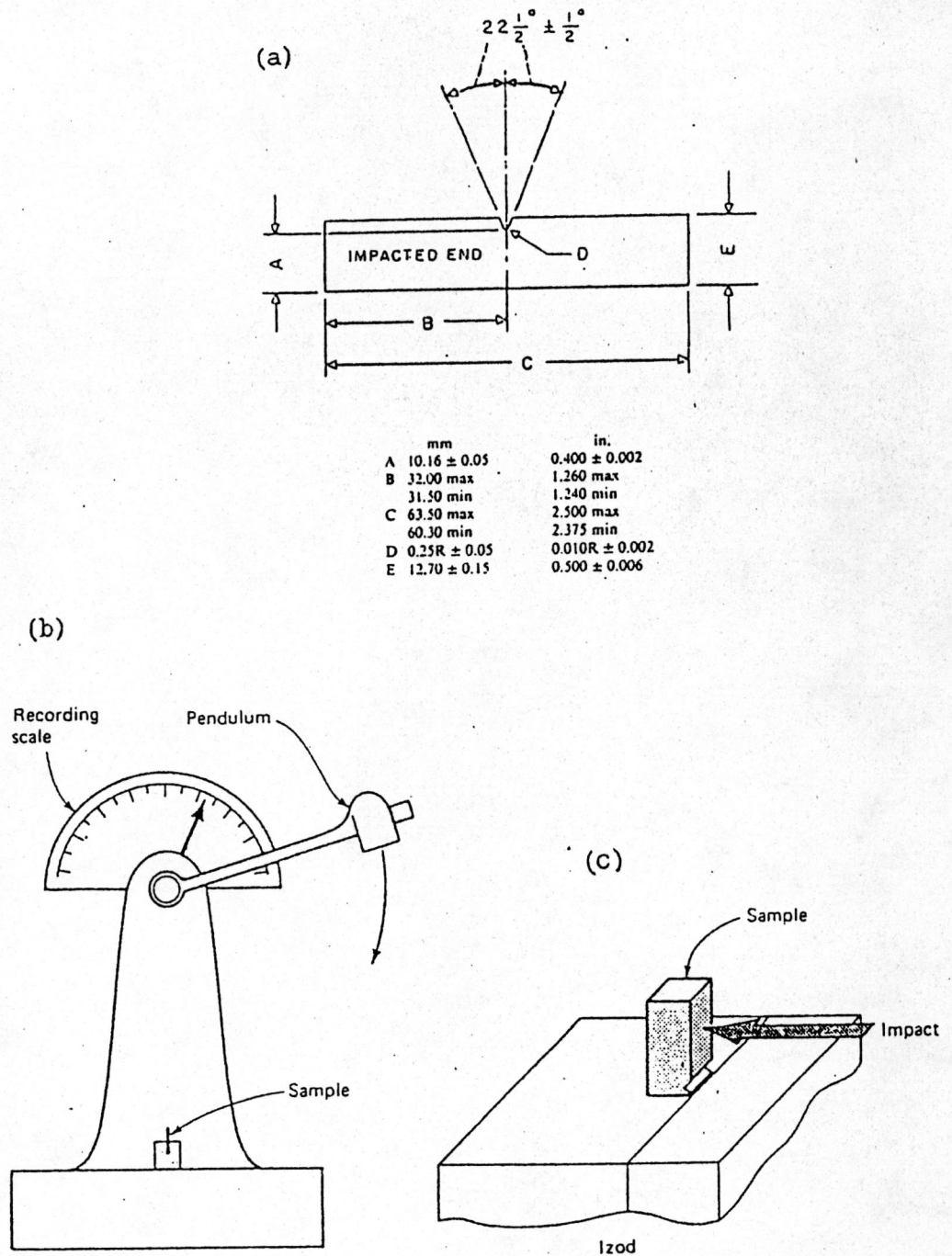


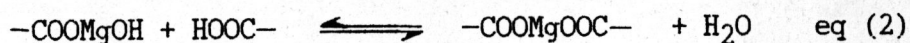
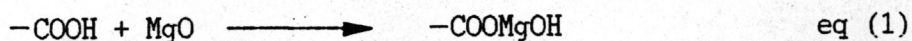
Figure 5 Notched Izod Impact Testing :

- (a) dimensions of Izod type test sample
- (b) machine for Izod test
- (c) the position of sample on the machine

APPENDIX D

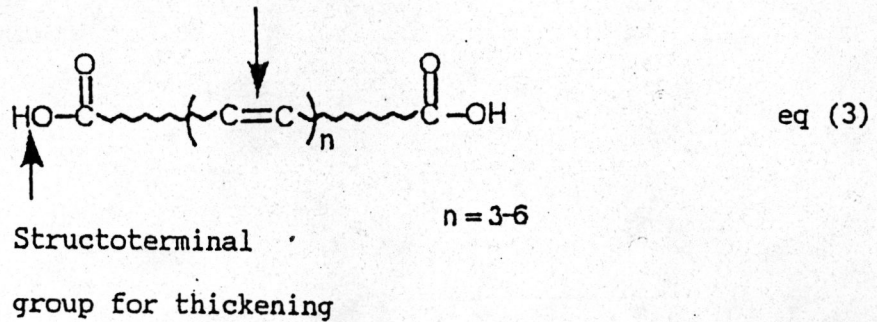
Thickening Reaction : Some Mechanisms Were Proposed

In the formulation of SMC compound, various fillers and thickening agents are used for adjusting the desired rheological properties of the molding compound. Regarding the reaction mechanism itself, two theories have been proposed to account for the observed 1000 fold increase in the viscosity of a linear polyester resin after its reaction with alkaline earth metal oxides. The common starting point for both the mechanisms is the formation of basic and neutral salts according to the following reactions :



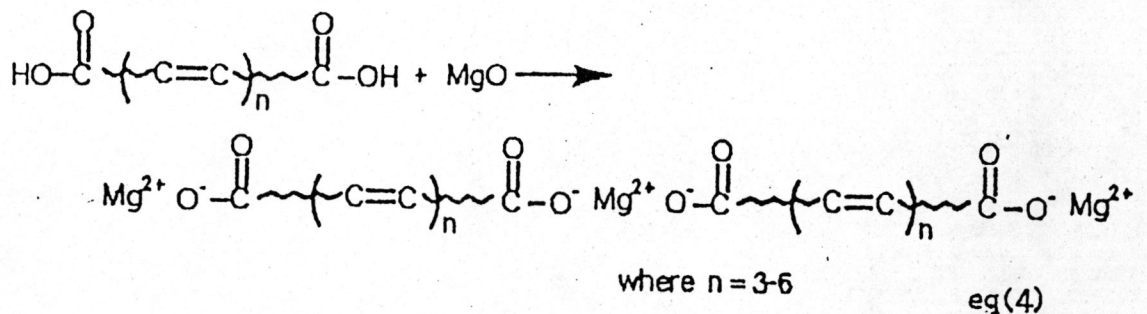
The molecular structure of the unsaturated polyester resin would be expected to have an effect on the rheological properties of the molding compounds during thickening reaction or cure. As illustrated in equation 3, in the general purpose unsaturated polyester resin contains structopendant reactive groups for crosslinking and structoterminal reactive groups for thickening reaction.

Structopendant group for crosslinking



The reaction of MgO with polyester resin containing the carboxyl end groups leads to compounds with very high viscosities and it is referred to as the thickening reaction of polyester resin. This increase in viscosity has been extensively studied by several workers (1-3). Different mechanisms were proposed.

Rao and Gandhi (1), and more recently Judas and Ernest Marechal (2), described the thickening reaction as the formation of a polymeric neutral salt. The following reaction may take place to convert into the viscous SMC paste as illustrated in equation 4.



From the formation of basic or neutral magnesium carboxylates, Vancso-Szmercsanyi and Szekely-Pecsi (3) proposed a mechanism involving a two-step reaction between the carboxyl end groups and metal oxide, with initial formation of basic or neutral salts, followed by the complexation of these salts by the ester groups in the chains and/or the hydroxyl end groups, by coordinate bonding between the ester groups and magnesium ions, leading to a network structure.

According to the results in CHAPTER III, it is speculated that the viscosity increases with increasing ion concentrations from which indicate that the reaction is highly diffusion controlled. Vancso-Szmercsanyi (3) connects the polymer molecules by coordination bonds through the metal ions. Based on this proposed mechanism, it is essential that new polymeric systems of enhanced molecular mass and of changed structure are formed.

A polymer molecule comprising several ligand groups (or functional groups) can be considered as a polydentate macroligand. The most common ligand in these systems is the COOH group or COO⁻ anion. In this case the viscosities of coordination polymers from the reactions between unsaturated polyester terminated by the free COOH or alcoholic OH groups and Mg²⁺ ions are presented. Interrelation between the number of ions and the viscosity of viscous flow was attempted to connect with other physical and chemical characteristics of the system.

Vancso-Szmercsanyi and Szekely-Pecsi proposed the mechanism of thickened polyester which is classified as polymer with the COOH or COO^- functionality. This situation is somewhat complicated, as polyester molecules contain additional functional groups capable of coordination because the electron donor oxygen atoms are presented in various bonds. Such ligand groups are illustrated in Figure 1.

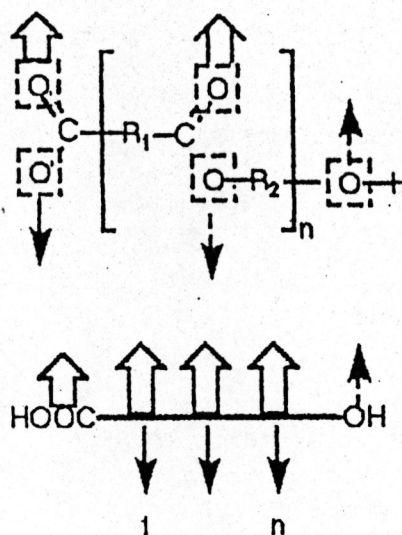


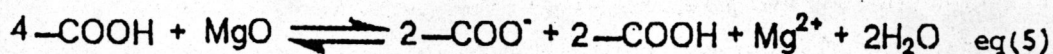
Figure 1 Ligand groups of unsaturated polyesters capable of forming coordinated bond in coordination reaction.

Coordination of the donor atom to the central metal ion depends on the types and coordination number of the metal ions, on the ratio of ligands to central ions, and on steric factors. In general Mg^{2+} ions usually react with a coordination number of 6, scarcely of 4. In the present case, Mg^{2+} ions react with a coordination number of 6.

Definition of the "r" value : the molar ratio of Mg^{2+} ions to the COOH end groups of the starting polyester.

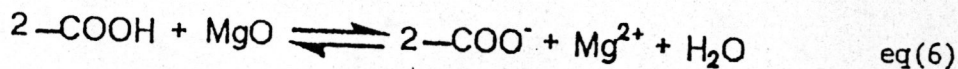
As the r value is changed, the following statements can be occurred :

At $r = 0.25$



At this ratio, eight atoms of donor oxygen share one metal ion, disregarding the water formed in the reaction (eq 5) thus an excess ligand is present in the system even if only the COOH and COO^- end groups are involved in the coordination. This means that there is no theoretical possibility for other oxygen atoms of the polyester molecule to coordinate. Consequently, only a moderate increase in molecular mass or relatively high viscosity takes place.

At $r = 0.5$



In this case four donor oxygen atoms share one metal ion. Thus the central ion (Mg^{2+}) has two additional active sites available for further coordination, depicted in Figure 2, for saturation of the coordination sphere of the magnesium ion.

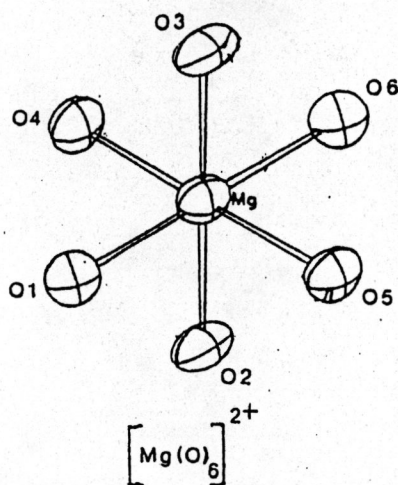
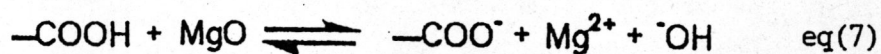


Figure 2 Coordinated model of the donor oxygen atoms able to sharing one magnesium ion possibly occurred in the coordination mechanism.

In this regard, the terminal alcoholic OH groups of polyester (at the chain end opposite to the COOH groups) are primary involved. By linking these OH groups to the vacant coordination sites, the molecular mass or viscosity is considerably increased.

At $r = 1.0$

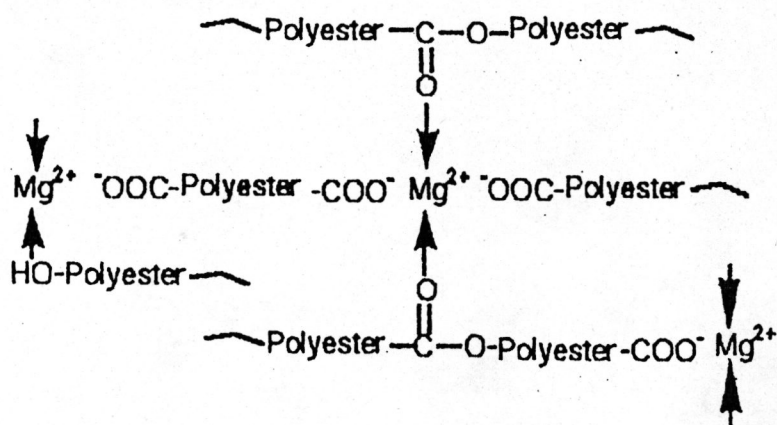


In this reaction as many as three oxygen atoms share one metal ion if only the COO^- and OH^- anions are accounted for.

Thus, in addition to the terminal alcoholic groups, the metal ions can coordinate the ester groups. The result is a further increase in apparent molecular mass with very high viscosity. In addition, a structural change can form a "coordination network".

At this point, it is worth referring to one of Szmercsanyi and Pecsí's earlier experiments (3). When MgO was added to a polyester terminated by OH groups at both ends, no viscosity enhancement could be achieved. On the other hand, when ionization of MgO was achieved by the addition of a low molecular acid, such as acetic acid, a considerable increase in viscosity was obtained. It was noted that in this reaction the enhanced molecular mass indicated by the higher viscosity is attributed to the coordination of backbone ester groups to metal ions.

According to the overall mechanisms that have been proposed by Vancso-Szmercsanyi and Szekely-Pecsí, summary to explain the increase in viscosity can be illustrated in the following diagram.



It is important to mention that among the possible coordination bonds, the ester carbonyl-metal ion bonds are most sensitive to thermal decomposition; therefore, the most important structural change in this system is related to the formation of interchange bridges by coordinative bonds (CO-Mg bonds).

In these cases, a decrease in the apparent molecular mass is involved by a partial decomposition of the "coordination network". Based on the mentioned situation and the observation of the melt viscosity of viscous resin mix that contained various Mg^{2+} ions, a decrease in viscosity when approaching to the molded temperature (140-150°C) was found. In addition, Szmercsanyi and Peci (3) demonstrated that the coordinated bond which contained metal ions such as Zn^{2+} or Mg^{2+} was decreased by increasing temperature. This can be attributed to the decomposition of the weaker coordinative bond at elevated temperature.

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APPENDIX E

Composite Properties : Some Theoretical Properties on Tensile Modulus Calculation

In the analysis of the theoretical properties of different types of composites, various analytical models and failure theories have been used. There are different considerations, in SMC composite involved in the case of randomly oriented discontinuous fiber composite.

One of the most important factors determining the properties of composites is the relative proportions of the matrix and reinforcing materials. The relative proportions can be given as the weight fractions or the volume fractions. The weight fractions are easier to obtain during fabrication than the volume fractions are exclusively used in the theoretical analysis of composite materials. It is thus desirable that the expressions for conversion between the weight fractions and volume fractions be handy. These expressions are derived for a two-phase material and then generalized to a multiphase material.

Consider a volume v_c of a composite material that consists of volume v_f of the fibers and volume v_m of the matrix material. Let w_c , w_f and w_m represent the corresponding weights of the composite material, fibers and the matrix material, respectively. Let the volume fraction and weight fraction be denoted by the capital letters V and W respectively. The conversion between the weight fraction and volume fraction can be obtained by equation 1.

$$V_f = \frac{\rho_c}{\rho_f} W_f$$

eq (1)

$$V_m = \frac{\rho_c}{\rho_m} W_m$$

Equation 1 has been derived for a composite material with only two compositions but can be generalized for an arbitrary number of compositions. The generalized equations are:

$$\rho_c = \sum_{i=1}^n \rho_i V_i$$

eq (2)

$$V_i = \frac{\rho_c}{\rho_i} W_i$$

The density of composite materials in terms of weight fraction can be obtained by equation 3.

$$\rho_c = \frac{1}{(W_f/\rho_f) + (W_m/\rho_m)}$$

eq (3)

In calculation it is necessary to express resin-to-glass ratio in terms of volume fraction rather than percentage weight or weight fraction (1). To obtain equation 4, one substitutes equation 1 with the expression of ρ_c in equation 3.

$$V_f = \frac{W_f/\rho_f}{W_f/\rho_f + W_m/\rho_m} \quad \text{eq (4)}$$

where W_f is the weight fraction of the fiber

ρ_f is the density of the fiber

ρ_m is the density of the matrix (resin)

Since the volume fraction of the fiber content is denoted as V_f the volume fraction of the resin matrix (V_m) should therefore be substituted as $1 - V_f$.

Tensile Modulus Calculation

Nevertheless, it is possible to predict the strength of a composite on the basis of the tensile moduli of the compositions.

$$E_c = (E_f \times V_f \times \beta) + (E_m \times V_m) \quad \text{eq (5)}$$

when E_c = tensile modulus of the composite

E_f = tensile modulus of the fibers

E_m = tensile modulus of the matrix or resin

V_f = volume fraction of fibers

V_m = volume fraction of the matrix or resin

β = 1.0 for unidirectional fibers

= 0.5 for bidirectional fibers

= 0.375 for chopped strand mat

A worked out example should make it clear how to use these equations, considering a chopped strand mat composite with a 6:4 resin-to-glass ratio in polyester resin. Fiber density is given as 2.55 g/cm^3 and resin density 1.13 g/cm^3 . Elastic modulus of the fiber (E_f) is 70,000 MPa. Elastic modulus of polyester resin (E_m) is 3,138 MPa.

Set out the figures in terms of weight expressed as a fraction:

$$\text{glass fiber, } W_f = 0.4$$

$$\text{resin, } W_m = 0.6$$

Now one uses equation 4 to determine the volume fraction of the fiber:

$$V_f = \frac{0.4/2.55}{0.4/2.55 + 0.6/1.13}$$

$$= \frac{0.157}{0.157 + 0.531}$$

$$= 0.228$$

$$V_m \text{ then follows as } 1 - 0.228 = 0.772$$

Now one uses equation 5 to determine the tensile modulus of the composites:

$$\text{For } = 0.375, E_c = (70,000 \times 0.228 \times 0.375) + (3,138 \times 0.772)$$

$$= 5,985 + 2,422$$

$$= 8,407 \text{ MPa}$$

These equations can be used to estimate the performance of virtually, any composition of composite, even those inclusive of fillers (2). In that case the equation 5 must be correlated if the filler has given effect to strength. The equation 4 must be extended to take into account the effect of filler proportion on the respective volume fractions of fiber and resin, i.e.

$$V_f = \frac{W_f/\rho_f}{W_f/\rho_f + W_m/\rho_m + W_x/\rho_x} \quad \text{eq (6)}$$

$$\text{and } V_m = \frac{W_f/\rho_m}{W_f/\rho_f + W_m/\rho_m + W_x/\rho_x} \quad \text{eq (7)}$$

where W_x = weight of filler
 ρ_x = density of filler

REFERENCES

1. Agarwal, B.D., and Lawrence J. Broutmar, Analysis and Performance of Fiber Composites, pp. 18-20 John Wiley & Sons, New York, 1st ed., 1980.
2. Warring, R.H., The Glass fiber Handbook, pp. 152-153 Arnus Book Ltd., Birmingham, 1983.

APPENDIX F

AN ARRANGEMENT OF REINFORCEMENT: APPLICATION TO STRUCTURAL SMC

The arrangement of the glass reinforcement is of equal importance with respect to strength of the final product.

Consider three cases:

- i) when all glass strands are laid parallel (unidirectional)
- ii) when half of the strands are laid at right angles to the other half (bidirectional)
- and iii) when the strands are arranged in a random manner (isotropic direction).

These directional strength patterns are shown in Figure 1.

When all the strands are laid parallel to each other, maximum strength results in one direction. This strength is supplied for end uses such as solid rods or solid bars. Product application would include golf clubs, and fishing rods.

When half the strands are laid at right angles to the other half, strength is highest in those two directions. Strength in any one direction is less than with parallel arrangement. This pattern of glass reinforcement is used in structural shapes.

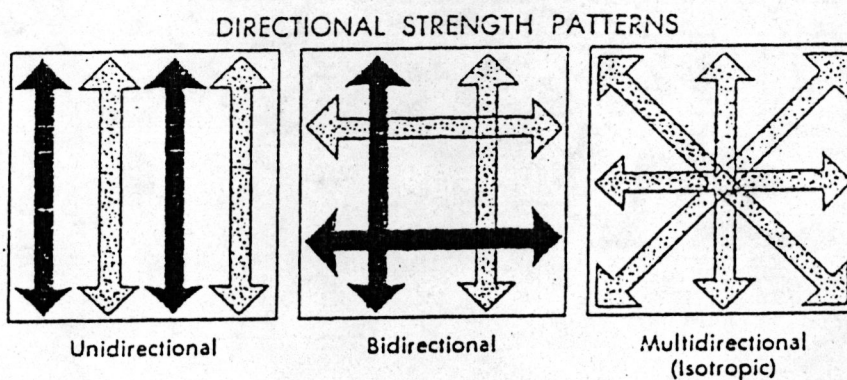


Figure 1 Directional strength patterns

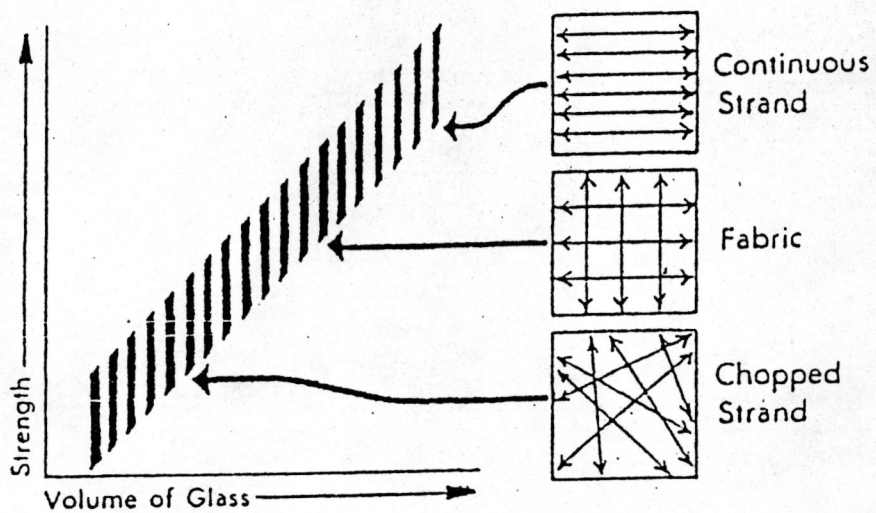


Figure 2 Type of glass reinforcement determines maximum strength in a given direction

When glass fibers are arranged in a random manner (isotropic direction), strength is equal in all directions. This arrangement is generally found in safety helmets, chairs, molded parts of SMC, and machine housings.

The relationship of amount of glass, strength characteristics, and arrangement of glass is shown in Figure 2.

For the effect of arrangement of glass mat to property of SMC, Ralph B. Jutte, Owens-Corning Fiberglas Co., Technical Center, Ohio, a report developed versatile of structural SMC materials and presented at the Congress and Exposition, Detroit, Michigan, February, 1978. It is briefly described as follows :

A versatile family of high-strength SMC materials has been developed. The basic systems are designated SMC-R, SMC-C, and SMC-D. Each fiber type denoted: R as random fiber, C as continuous fiber and D as directional fiber, and indicated the configuration of the reinforcement used. Combination of fibers allow other systems to be considered also, such as: SMC-C/R and SMC-D/R. These materials are processable on conventional SMC machines with minor modifications, and thus provide the compounder with the ability to produce a structural grade SMC with a minimum capital investment.

Figure 3 shows the SMC type designates reinforcement for configuration used, and Figure 4 shows that the combination of fibers can be used to expand basic systems.

SMC-R (Figures 3 and 4) is defined as RANDOM FIBER SMC. Most SMC used today is SMC-R. The usual reinforcement is chopped roving, although chopped strand mat is also suitable. SMC-R has application in parts where strength uniformity is important. It is considered isotropic in an unmolded state, but becomes anisotropic upon flowing in the mold. The schematic diagram of SMC-R production process is shown in Figure 5.

SMC-C (Figure 3) is defined as CONTINUOUS FIBER SMC. In this, SMC-C system is capable of producing the maximum mechanical properties in the direction of the fibers, but with low values when tested perpendicular to the fiber direction. Combining plies at various angles to one another could be done to minimize the severe anisotropy of mechanical properties, and to "build" specific property performance characteristics as needed particularly modulus and impact (Figure 6). Strategic placement in parts of SMC-C can be used to strengthen specific areas.

SMC-C/R (Figure 4) is the incorporation of random chopped fiber into the SMC-C system which improves its processing and charge handling prior to molding. Use of continuous fibers significantly increases the modulus values, above those achievable with SMC-R systems at comparable glass contents.

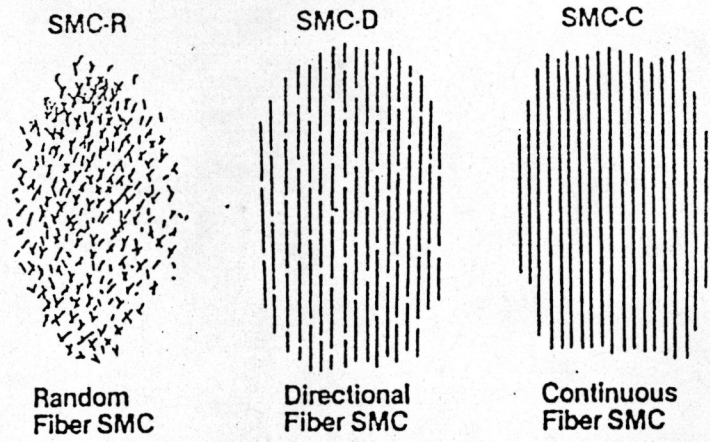


Figure 3 SMC type designates reinforcement configuration used

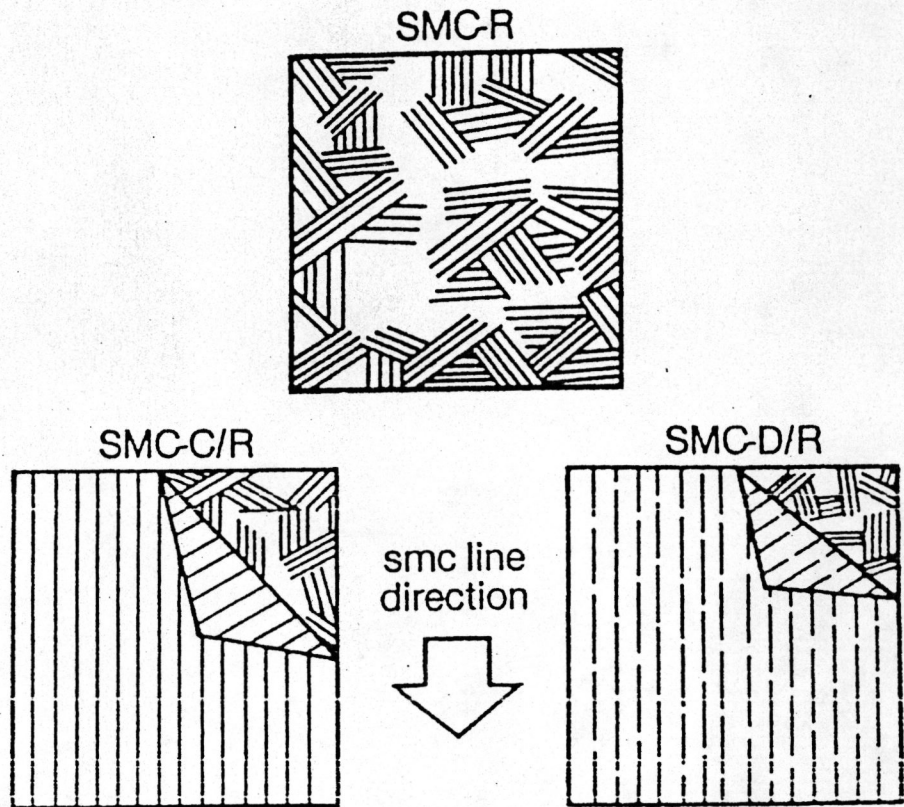


Figure 4 Different types in combination of structural fiber

SMC-D (Figure 3) is defined as DIRECTIONAL FIBER SMC. It contains fibers of four inches or longer in length in a discontinuous unidirectional pattern. It improved molding characteristics relative to SMC-C. Cutting the continuous fibers allows the material to flow in the fiber direction as well as in the transverse direction.

SMC-D/R (Figure 4), requires generally the SMC-D to be made in combination with some random fibers. The schematic diagram of SMC-D/R on line production processing, utilizes two roving choppers, is shown in Figure 7. Mechanical properties of SMC-D systems are expected to fall between those of SMC-R and SMC-C systems of comparable glass content with values approaching those of SMC-C as the length of the long unidirectional fibers increase. Thus, this system provides a compromise between the good flow characteristics of SMC-R and the superior mechanical properties of SMC-D.

COST AND PERFORMANCE COMPARISONS

Considering the different SMC-R systems, an increase in the glass content provides a weight savings but the increased material costs negates any cost saving. When the SMC-D and SMC-C systems are used effectively with the stress applied in the direction, additional weight and cost savings over the SMC-R systems can be expected.

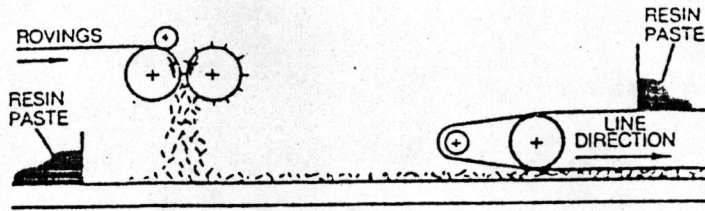
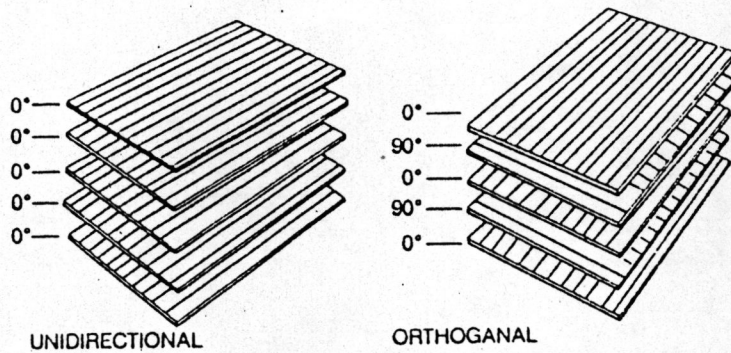


Figure 5 SMC-R production process



Note: A balanced ply construction is recommended. The flatter the laminate requires the more critical the balanced ply construction becomes to prevent warpage.

Figure 6 Example of laminate ply construction when using SMC-C

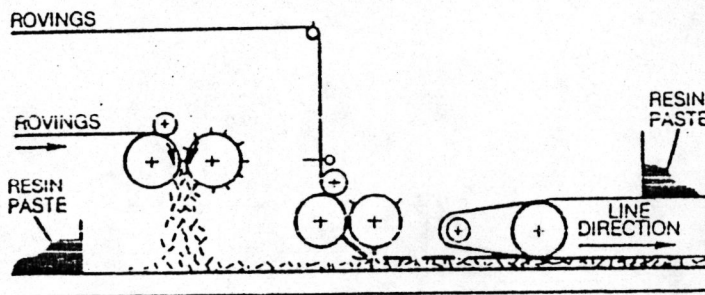


Figure 7 Schematic of SMC-D/R on-line production process utilizing two roving choppers

Comparing the various SMC system, the value of increased glass loading and fiber orientation is evident. The higher tensile strengths occurring from use of higher glass contents allow a reduction in thickness that more than offsets higher material costs. As a result, there is a significant weight and cost savings potentially available where higher glass type SMCs are applicable.

The molder is provided a materials system with which he can deliver mechanical properties and selective directional reinforcement in order to comply with special part requirements. This flexibility in reinforcement will lead to improved efficiency of design, which will result in minimum part cost and weight for any given applications.

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APPENDIX G

MOLDING PROBLEMS : CAUSES AND POSSIBLE REMEDIES

Defect	Possible causes	Remedies
Internal voids (Figure 1)	Press closed too rapidly	Introduce slow close in molding cycle
	Air trapping	1. Reduce speed of closure 2. Reduce mold temperature
	Material too hard	Use fresh material

(over)

continued

Defect	Possible causes	Remedies
Blistering (Figure 2)	Inadequate cure	Increase curing time
	Air entrapped between the layers of resin mat	Eliminate trapped air by good roled practice
	Too high a mold temperature (monomer vapors)	Lower mold temperature
Warpage (Figure 3)	One mold much hotter than the other mold	Reduce temperature differential of molds

(over)

continued

Defect	Possible causes	Remedies
Sticking (Figure 4)	Mold surface too rough	Polish surface or Chrome plate mold
	Curing time too short	Increase curing time
Surface porosity (Figure 5)	Air trapping due to: a. Material too stiff flow	1. Use fresh material 2. Decrease storage life or maturation state
	b. Low molding pressure	Increase pressure

(over)

continued

Defect	Possible causes	Remedies
Exuding (Figure 6)	a. Press closed too rapidly	1. Reduce speed of closure 2. Provide adequate venting
	b. Material has low viscosity	Increase storage life

MOLDING PROBLEMS

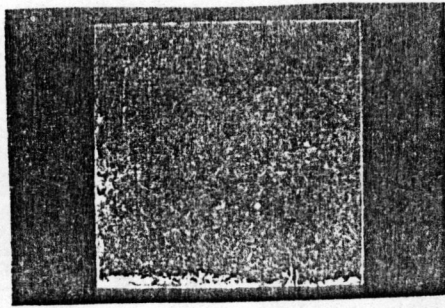


Figure 1 *Internal void*

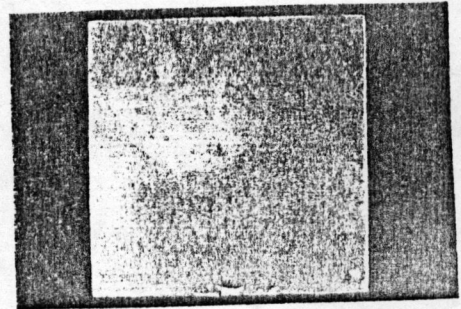


Figure 2 *Blistering*

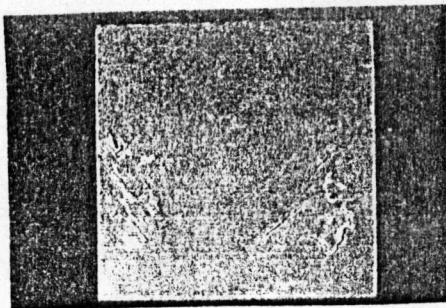


Figure 3 *Warpage*

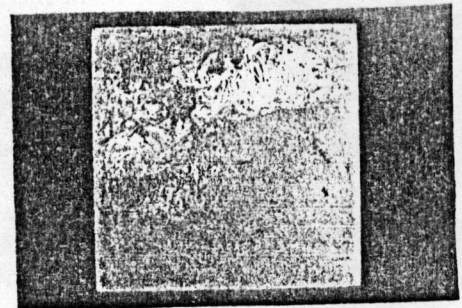


Figure 4 *Sticking*

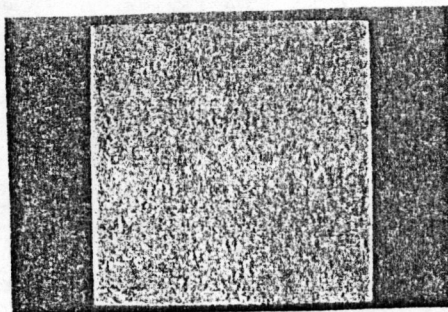


Figure 5 *Surface porosity*

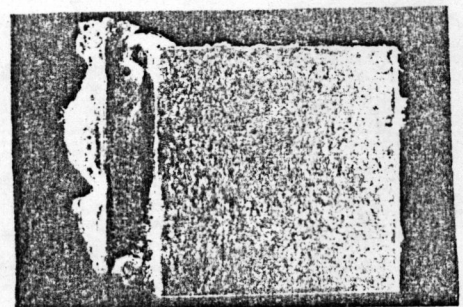


Figure 6 *exuding*

VITA

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